

ORIENTATION INDEPENDENT FUEL RESERVOIR CONTAINING LIQUID FUEL

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Orientation Independent Fuel Reservoir Containing Liquid Fuel

Cross-Reference to Related Applications

The instant application claims the benefit of U.S. Provisional Patent Application Nos. 60/460,406 (filed on April 7, 2003) and 60/411,353 (filed on September 18, 2002), the disclosures of which are incorporated by reference. The instant application is also a continuation-in-part application of U.S. Non-Provisional Patent Application No. 10/329,776, filed on December 27, 2002, the disclosure of which is also herein incorporated by reference.

This invention relates to liquid fuel cells in which the liquid fuel is directly oxidized at the anode. In particular, it relates to the reservoir for holding and metering or delivering the liquid fuel to the anode of a liquid fuel cell. This invention also relates to liquid fuel feed systems for micro fuel cell reformers.

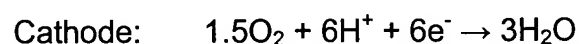
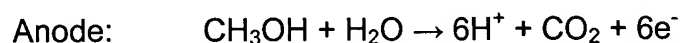
Background of the Invention

Electrochemical fuel cells convert reactants, namely fuel and oxidants, to generate electric power and reaction products. Electrochemical fuel cells generally employ an electrolyte disposed between two electrodes (an anode and a cathode). An electrocatalyst is needed to induce the desired electrochemical reactions at the electrodes. Liquid feed solid polymer fuel cells operate in a temperature range of from about 0 °C to the boiling point of the fuel, *i.e.*, for methanol about 65 °C, and are particularly preferred for portable applications. Solid polymer fuel cells include a membrane electrode assembly ("MEA"), which comprises a solid polymer electrolyte or proton-exchange membrane, sometimes abbreviated "PEM", disposed between two electrode layers. Flow field plates for directing the reactants across one surface of each electrode are generally disposed on each side of the membrane electrode assembly.

There is typically a backing layer (or gas diffusion layer) between the flow field plate and the MEA.

A broad range of reactants have been contemplated for use in solid polymer fuel cells, and such reactants may be delivered in gaseous or liquid streams. The oxidant stream may be substantially pure oxygen gas, but preferably a dilute oxygen stream such as found in air, is used. The fuel stream may be substantially pure hydrogen gas, or a liquid organic fuel mixture. A fuel cell operating with a liquid fuel stream wherein the fuel is reacted electrochemically at the anode (directly oxidized) is known as a direct liquid feed fuel cell.

A direct methanol fuel cell ("DMFC") is one type of direct liquid feed fuel cell in which the fuel (liquid methanol) is directly oxidized at the anode. The following reactions occur:



The hydrogen ions (H^+) pass through the membrane and combine with oxygen and electrons on the cathode side producing water. Electrons (e^-) cannot pass through the membrane, and therefore are collected and flow from the anode to the cathode through an external circuit driving an electric load that consumes the power generated by the cell. The products of the reactions at the anode and cathode are carbon dioxide (CO_2) and water (H_2O), respectively. The open circuit voltage from a single cell is about 0.7 to 1 volt. Several direct methanol fuel cells are connected in series to obtain greater voltage.

Other liquid fuels may be used in direct liquid fuel cells besides methanol -- e.g., other simple alcohols, such as ethanol or ethylene glycol, or dimethoxymethane, trimethoxymethane, hydrazine and formic acid. Further, the oxidant may be provided in

the form of an organic fluid having a high oxygen concentration – *i.e.*, a hydrogen peroxide solution.

A direct methanol fuel cell may be operated on aqueous methanol vapor, but most commonly a liquid feed of a diluted aqueous methanol fuel mixture is used. It is important to maintain separation between the anode and the cathode to prevent fuel from directly contacting the cathode and oxidizing thereon (called “cross-over”). Cross-over results in a short circuit in the cell since the electrons resulting from the oxidation reaction do not follow the current path between the electrodes. To reduce the potential for cross-over of methanol fuel from the anode to the cathode side through the MEA, very dilute aqueous mixtures of methanol (for example, about 5 per cent of methanol in water, wherein the methanol concentration is expressed in methanol weight as per cent of the total weight of the aqueous mixture) are typically used as the fuel streams in liquid feed DMFCs.

The proton exchange membrane (PEM) is a solid, organic polymer, usually polyperfluorosulfonic acid, that comprises the inner core of the membrane electrode assembly (MEA). Commercially available polyperfluorosulfonic acids for use as PEM are sold by E.I. DuPont de Nemours & Company under the trademark NAFION®. Alternatively, composites of porous polymeric membranes impregnated with perfluoro ion exchange polymers, such as offered by W.L. Gore & Associates, Inc., can be used as the proton exchange membranes. The PEM must be hydrated to function properly as a proton (hydrogen ion) exchange membrane and as an electrolyte.

For efficient function of the fuel cell, the liquid fuel should be controllably metered or delivered to the anode side. The problem is particularly acute for fuel cells intended to be used in portable applications, such as in consumer electronics including cell phones, where the fuel cell orientation with respect to gravitational forces will vary.

Traditional fuel tanks with an outlet at the bottom of a reservoir, and which rely on gravity feed, will cease to deliver fuel when the tank orientation changes. In addition, dipping tube delivery of a liquid fuel within a reservoir varies depending upon the orientation of the tube within the reservoir and the amount of fuel remaining in the reservoir. Accordingly, to facilitate use of liquid fuel cells in portable electronic devices, a liquid fuel reservoir that controllably holds and delivers fuel to a liquid fuel cell, regardless of orientation, is desired.

A liquid fuel reservoir containing a wicking member, such as a urethane foam, is disclosed in co-pending U.S. Non-Provisional Patent Application No. 10/183,943, filed June 28, 2002.

Summary of the Invention

The first aspect of the invention relates to a fuel reservoir for a liquid fuel cell or microreformer. This fuel reservoir has a container having walls that define a volume for holding a liquid fuel for the liquid fuel cell or microreformer, wherein the container has an outlet passageway through one of the walls for the exit of the liquid fuel to a location exterior to the container. Preferably, the outlet passageway contains no wicking material inside, especially in the portion of the outlet passageway that penetrates one of the walls of the container. The container may have a regular or irregular cross-sectional shape depending upon the application. Examples of regular cross-sectional shapes are triangular, quadrilateral (e.g. rectangular, square, parallelogram, and trapezoid which is a quadrilateral shape having two parallel sides), pentagon, circular, oval, and elliptic shapes. The walls of the container can be made of a rigid or flexible material. When the container walls are made of a flexible material, the walls are collapsible allowing for easier stowage of an empty liquid fuel reservoir and allowing a liquid fuel reservoir filled with liquid fuel to better adapt to a space inside a fuel cell in which the reservoir may be

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installed. A wicking structure is disposed within the volume of the container, wherein the wicking structure comprises a wicking structure material which can wick the liquid fuel and wherein the liquid fuel wicked into the wicking structure material can subsequently be discharged out of or released from the wicking structure material. A
5 retainer is preferably provided to hold the wicking structure in a desired orientation within the container volume. When the liquid fuel reservoir contains the liquid fuel, at least a portion of the liquid fuel wicks into the wicking structure material. Such liquid fuel wicked into the wicking structure material subsequently may be delivered or metered out of the wicking structure material for use in a fuel cell or microreformer via
10 the outlet passageway which communicates with the wicking structure. The liquid fuel may be metered or delivered from the wicking structure material to the fuel cell with a liquid delivery means, such as a pump, in fluid communication with the outlet passageway. The liquid fuel reservoir also may include an inlet through the container, said inlet optionally having a one-way valve to permit gas or liquid flow into the volume
15 of the container and prevent the backflow of any fluid out of the container.

After the liquid fuel in the reservoir has been discharged, partially or completely, the outlet passageway or inlet may be used to introduce replenishing liquid fuel into the volume of the container to replace any spent liquid fuel making the fuel reservoir recyclable. Optionally, the container has a sealable cap comprising a membrane
20 through which replenishing liquid fuel can be introduced into the volume of the container upon puncture, e.g. by a needle of a syringe, of the membrane. The membrane should be made of a material resistant to the liquid fuel and puncturable by the needle, which material can reseal after the needle is withdrawn.

The wicking structure material extends to or near at least one extremity of the
25 container remote from the outlet passageway, so as to permit liquid fuel located at such

extremity to be wicked through the wicking structure material to the outlet passageway. Preferably, the wicking structure material extends to or near all extremities of the container remote from the outlet passageway, so that all the liquid fuel in the volume maintains, regardless of the orientation of the liquid fuel reservoir and the stage of liquid fuel depletion, fluid communication with the outlet passageway of the container at least via capillarity.

In a preferred embodiment of the liquid fuel reservoir, the volume of the container has a longest dimension. The wicking structure material has a free rise wick height of at least one half of the container volume's longest dimension (more preferably at least the container volume's longest dimension).

The liquid fuel reservoir of the invention can contain a liquid fuel for liquid fuel cells. The liquid fuel can contain or be an aqueous mixture of a simple alcohol, such as ethanol, ethylene glycol, or preferably methanol. The liquid fuel can also be a liquid containing dimethoxymethane, trimethoxymethane, hydrazine or formic acid. To increase the safety when the liquid fuel reservoir is used, the liquid fuel can further include an ingestion deterrent and/or flame brightening additive. Examples of the ingestion deterrent are an additive, such as Bitrex (denatonium benzoate), that adds a bad flavor, or an additive, such as syrup of ipecac, that can induce vomiting upon ingestion. Flame brighteners are typically salts known in the art.

When the ingestion deterrent and/or flame brightening additive is included in the liquid fuel, the liquid fuel stored in the liquid fuel reservoir is preferably exposed to an impurities scavenger, which comprises one scavenging substance or a mixture of scavenging substances, in order to remove the ingestion deterrent and/or flame brightening additive before being fed to the liquid fuel cell or micro reformer. However, even if the ingestion deterrent and/or flame brightening additive is not included in the

liquid fuel, the liquid fuel stored in the liquid fuel reservoir may preferably also be exposed to the impurities scavenger before being fed to the liquid fuel cell or micro reformer in order to remove any impurities in the liquid fuel that may poison the components, e.g. the catalysts, electrodes or membrane, in the liquid fuel cell or micro reformer. The scavenging substance can be an impurities absorbent or adsorbent, such as activated carbon, e.g. activated charcoal, amorphous carbon, e.g. carbon black, graphite powders having a high surface area, expanded graphite, silica, silicate, e.g. aluminosilicate (e.g. Fullers Earth, CAS# 8031-18-3) and diatomaceous earth, exchange resins, zeolites, molecular sieves or filter agents, e.g. Celatom FW80, CAS# 68855-54-9, capable of removing the ingestion deterrent, flame brightening additive and/or the impurities in the liquid fuel. Preferably, the scavenging substance is activated carbon. The scavenging substance can be in the form of powders or granules either in a loosen state or supported on a substructure. The particle size of the scavenging substance can be from about 1 nm to about 1 cm, preferably 10 μm to 5 mm, and more preferably 50 μm to 1 mm. The typical surface area of the scavenging substance is about 50 m^2/g .

The impurities scavenger can be inside (a) at least one porous internal compartment of the liquid fuel reservoir, (b) the outlet passageway of the liquid fuel reservoir, and/or (c) a filter cartridge having an inlet port and outlet port, wherein the inlet port is attached to the exit of the outlet passageway, and the outlet port can be connected to a liquid fuel cell or micro reformer. The at least one porous internal compartment is inside the container of the liquid fuel reservoir, wherein the porous internal compartment comprises at least one porous wall enclosing an internal volume holding the impurities scavenger. The at least one porous wall is made of a porous material, e.g. filter paper, a fabric of woven fibers, or a screen, that can allow the liquid

fuel to permeate. Preferably, all the walls of the porous internal compartment comprise the porous material, e.g. the porous internal compartment can be a porous pouch.

In some of the embodiments of the liquid fuel reservoir of the invention, the container contains at least one porous internal compartment holding an impurities scavenger. The porous internal compartment can be of any regular, e.g. rectangular, square or oval, or irregular shape, e.g. a pouch. The porous internal compartment, preferably, is of a generally flat shape of a rectangle, square or oval. Preferably, the at least one porous internal compartment is disposed near, or touching, at least a portion of the internal surface of at least one wall of the container, wherein more preferably the portion is free of the wicking structure. Even more preferably, the at least one porous internal compartment has corners that proximate the corners of the at least one wall of the container, and/or has edges that proximate the edges of the at least one wall of the container. Much more preferably, the container contains two porous internal compartments each disposed near, or touching, at least one portion of the internal surface of one of two opposing walls of the container, wherein most preferably the portion is free of the wicking structure. Even much more preferably, the corners and/or edges of each of the two porous internal compartments proximate the corners and/or edges, respectively, of the corresponding opposing walls.

In some of the embodiments of the liquid fuel reservoir of the invention having a liquid fuel containing an ingestion deterrent, when the liquid fuel reservoir is of a disposable variety, the liquid fuel reservoir and the filter cartridge containing the impurities scavenger can be separate entities, so that if the liquid fuel in the reservoir is consumed, the ingestion deterrent would still be effective. In some of the embodiments of the liquid fuel reservoir of the invention having a liquid fuel containing an ingestion deterrent, when the liquid fuel reservoir is used to supply liquid fuel to a liquid fuel cell,

the liquid fuel reservoir can be in fluidic communication with the filter cartridge containing the impurities scavenger, so that the impurities scavenger can render the liquid fuel acceptable to the liquid fuel cell. The filter cartridge can be permanently affixed to the liquid fuel reservoir, assuring that any leaked liquid fuel would be treated.

5 The liquid fuel reservoir and the filter cartridge can be supplied as separate entities, which can be assembled together by the user and installed into a liquid fuel cell. The filter cartridge can be designed to specifically not mount onto the liquid fuel reservoir, but mount in separate locations of the liquid fuel cell thereby preventing the user from assembling the two units and having access to untreated fuel. The liquid fuel can be
10 driven from the liquid fuel reservoir by a pressurizing mechanism or drawn from the liquid fuel reservoir by a pump. The impurities scavenger can be replaced as needed to assure a clean liquid fuel supply to the liquid fuel cell.

Another aspect of the invention provides a package for delivering a fuel to a liquid fuel cell having a container defining a volume for holding a liquid fuel for a liquid
15 fuel cell. A wicking structure is held within the container volume and at least a portion of the liquid fuel wicks into the wicking structure. A retainer holds the wicking structure in a desired orientation within the container volume. An outlet passageway through the container communicates with the wicking structure in the container. Once a liquid fuel is introduced into the volume of the container, such liquid fuel may be metered or
20 delivered from the wicking structure and through the outlet passageway with a pump or other metering or liquid delivery means separate from the fuel wicking structure in the container. Preferably, the package is provided with an inlet optionally having a one-way valve to permit gas or liquid flow into the volume of the container but preventing undesired release of gas and fuel from the container. The structures of the container,

retainer and wicking structure preferably are the same as those described with reference to the liquid fuel reservoir of the first aspect of the invention disclosed herein.

A further aspect of the invention is a method of dispensing a liquid fuel using a fuel reservoir of the invention. The method includes the steps of: (a) providing a
5 container defining a volume having at least one extremity, said volume holding the liquid fuel; (b) providing a wicking structure within the volume, the wicking structure extending to the at least one extremity, wherein the wicking structure comprises a wicking structure material into which the liquid fuel can wick and from which the liquid fuel can be discharged; (c) wicking at least a portion of the liquid fuel into the wicking structure;
10 and (d) delivering the liquid fuel from the wicking structure to a location exterior to the container through an outlet passageway in the container that communicates with the wicking structure in the container. In a preferred embodiment of the method, the wicking structure in step (b) is held by a retainer in a desired orientation within the volume of the container. Step (d) is preferably carried out by pumping the liquid fuel out
15 of the wicking structure to the exterior location. A gas, such as air or nitrogen, may be introduced into an inlet formed through the container. Preferably, the inlet has a one-way valve to permit gas flow into the container volume without allowing any gas or liquid to leave the container.

The method of dispensing a liquid fuel has a primary application for dispensing
20 liquid fuels, such as simple alcohols, e.g. methanol, ethanol, ethylene glycol, or mixtures thereof, dimethoxymethane, trimethoxymethane, formic acid, hydrazine and hydrogen peroxide, for use in liquid fuel cell applications. The method of dispensing the liquid fuel also has application for the delivery of fuel to microreformers, which fuels also include hydrocarbons, diesel fuel, gasoline, jet fuel, higher molecular weight alcohols and
25 similar fuels. The structures of the container, retainer and wicking structure preferably

are the same as those described with reference to the liquid fuel reservoir of the first aspect of the invention disclosed herein.

In yet another aspect of the invention, a method of assembling a fuel cartridge for a liquid fuel cell includes the following steps: (a) providing a container having a proximal end and a distal end and defining a volume for holding a liquid fuel for a liquid fuel cell; (b) providing a cap to seal the distal end of the container; (c) providing a wicking structure within the volume and into which at least a portion of the liquid fuel wicks and from which said liquid fuel subsequently may be delivered or metered; (d) providing a retainer to hold the wicking structure in a desired orientation within the container volume; (e) mounting the wicking structure over at least a portion of the retainer; (f) attaching the retainer to the cap; and (g) slidably inserting the wicking structure and retainer into the volume of the container while inserting the cap on the distal end of the container. Once the fuel cartridge has been assembled, it may be filled with a liquid fuel, preferably liquid fuels intended for use in liquid fuel cell applications, such as simple alcohols, e.g. methanol, ethanol, ethylene glycol or mixtures thereof, dimethoxymethane, trimethoxymethane, formic acid, hydrazine and hydrogen peroxide, or liquid fuels intended for reformers, such as hydrocarbons, diesel fuel, gasoline, jet fuel, and higher molecular weight alcohols. Preferably, the liquid fuel is introduced into the container through the vent, outlet passageway, or a passageway formed through a wall of the container, such as the proximal end or a side wall. The structures of the container, retainer and wicking structure preferably are the same as those described with reference to the liquid fuel reservoir of the first aspect of the invention disclosed herein.

Brief Description of the Drawings

FIG. 1 is a schematic diagram of a liquid fuel delivery system used with a fuel cell to power a fuel cell driven portable electronic device such as a cellular telephone, wherein the liquid fuel delivery system comprises a liquid fuel reservoir of the invention;

FIG. 2 is an exploded top plan view of the liquid fuel reservoir having a container with a generally rectangular shape shown in FIG. 1 with portions of the drawing partially broken away to show certain structural components;

FIG. 3 is a top plan view of the assembled liquid fuel reservoir shown in FIG. 2;

FIG. 4 is a right end view partially in cross-section taken along line 4-4 of FIG. 3;

FIG. 5 is a longitudinal cross-sectional view taken along line 5-5 of FIG. 3;

FIG. 6 is left end elevational view partially broken away of an alternative liquid fuel reservoir having a housing with a generally cylindrical shape;

FIG. 7 is a front elevational view partially broken away of the fuel reservoir shown in FIG. 6;

FIG. 8 is a top plan view partially broken away of still another alternative liquid fuel reservoir having a housing with a generally cubic shape;

FIG. 9 is a front elevational view partially broken away of the liquid fuel reservoir of FIG. 8;

FIG. 10 is a top plan view partially broken away of a further liquid fuel reservoir having a housing with a generally cubic shape with an alternative configuration of wicking material;

FIG. 11 is a front elevational view partially broken away of the liquid fuel reservoir of FIG. 10;

FIG. 12 is a top plan view of another alternative liquid fuel reservoir having a housing with a generally rectangular cross-sectional shape with an alternative

configuration of wicking material, inlet and outlet tubes, and with portions of the drawing partially broken away to show certain structural components;

FIG. 13 is a side elevational view of yet another alternative liquid fuel reservoir opened at one end, and having an alternative configuration of wicking material, inlet and outlet tubes;

FIG. 14 is a top plan view of still another alternative liquid fuel reservoir having an alternative configuration of wicking material, inlet and outlet tubes, and with portions of the drawing partially broken away to show certain structural components;

FIG. 15 is a perspective view of a wicking structure defining a hollow core and having perforations therethrough;

FIG. 16 is a top plan view of the surface of a wicking material having slits formed therein;

FIG. 17 is a top plan view of a wicking material having expanded slits formed therein;

FIG. 18 is a schematic diagram of a liquid fuel reservoir viewed from the front with a wicking structure having the external volume, as defined below, minimized;

FIG. 19 is a schematic diagram of the liquid fuel reservoir of FIG. 18 presented from a perspective view;

FIG. 20 is a schematic diagram of a liquid fuel reservoir viewed from the front with an alternative wicking structure having the external volume minimized;

FIG. 21 is a schematic diagram of a liquid fuel reservoir similar to the reservoir of FIG. 20 viewed from the front with a wicking structure having the external volume minimized, wherein an outlet passageway is placed at a different location;

FIG. 22 is a schematic diagram of a liquid fuel reservoir viewed from the front with an alternative wicking structure having the external volume minimized;

FIG. 23 is a schematic diagram of a liquid fuel reservoir similar to the reservoir of FIG. 22 viewed from the front with a wicking structure having the external volume minimized, wherein an outlet passageway is placed at a different location;

FIG. 24 is a schematic diagram of a liquid fuel reservoir viewed from the front with an alternative wicking structure having the external volume minimized;

FIG. 25 is a schematic diagram of a liquid fuel reservoir similar to the reservoir of FIG. 24 viewed from the front with a wicking structure having the external volume minimized, wherein an outlet passageway is placed at a different location;

FIG. 26 is a schematic diagram of a liquid fuel reservoir viewed from the front with an alternative wicking structure having the external volume minimized;

FIG. 27 is a schematic diagram of a liquid fuel reservoir similar to the reservoir of FIG. 26 viewed from the front with a wicking structure having the external volume minimized, wherein an outlet passageway is placed at a different location;

FIG. 28 is a schematic diagram of a liquid fuel reservoir viewed from the front with an alternative wicking structure having the external volume minimized;

FIG. 29 is a schematic diagram of a liquid fuel reservoir viewed from the front with an alternative wicking structure having the external volume minimized;

FIG. 30 is a schematic diagram of a liquid fuel reservoir similar to the reservoir of FIG. 29 viewed from the front with a wicking structure having the external volume minimized, wherein an outlet passageway is placed at a different location;

FIG. 31 is a schematic diagram of a liquid fuel reservoir viewed from the front with an alternative wicking structure having the external volume minimized;

FIG. 32 is a schematic diagram of a liquid fuel reservoir similar to the reservoir of FIG. 31 viewed from the front with a wicking structure having the external volume minimized, wherein an outlet passageway is placed at a different location;

FIG. 33 is a schematic diagram of a recyclable or rechargeable liquid fuel reservoir having a sealable, detachable cap containing a membrane;

FIG. 34 is a schematic diagram of another recyclable or rechargeable liquid fuel reservoir having an outlet passageway containing a valve;

5 FIG. 35 is a schematic diagram of an alternative recyclable or rechargeable liquid fuel reservoir having a detachable cap at the end of an outlet passageway;

FIG. 36 is a schematic diagram of a liquid fuel reservoir similar to the reservoir of FIG. 18 viewed from the front with a wicking structure having the external volume minimized, wherein an outlet passageway is placed at a different location;

10 FIG. 37 is a schematic diagram of another liquid fuel reservoir similar to the reservoir of FIG. 18 viewed from the front with a wicking structure having the external volume minimized, wherein an outlet passageway is placed at a different location;

FIG. 38 is a perspective view of another liquid fuel reservoir according to the invention shown schematically with an alternative wicking structure having the external
15 volume minimized;

FIG. 39 is a perspective view of another liquid fuel reservoir according to the invention shown schematically with an alternative wicking structure having the external volume minimized; and

20 FIG. 40 is a perspective view of another liquid fuel reservoir according to the invention shown schematically with an alternative wicking structure having the external volume minimized.

FIG. 41 is a schematic vertical cross-sectional view of a liquid fuel reservoir according to the invention.

FIG. 42 is a perspective view of the liquid fuel reservoir of FIG. 41, wherein the liquid fuel reservoir is in the shape of a cylinder.

FIG. 43 is a schematic vertical cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 18 having at least one porous internal compartment.

5 FIG. 44 is a perspective view of the liquid fuel reservoir of FIG. 43.

FIG. 45 is a schematic horizontal cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 43 along line A-A, wherein the reservoir has one porous internal compartment.

10 FIG. 46 is a schematic horizontal cross-sectional view of another embodiment of the liquid fuel reservoir of FIG. 43 along line A-A, wherein the reservoir has two porous internal compartments.

FIG. 47 is a schematic horizontal cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 43 along line B-B, wherein the reservoir has two porous internal compartments.

15 FIG. 48 is a schematic horizontal cross-sectional view of another embodiment of the liquid fuel reservoir of FIG. 43 along line B-B, wherein the reservoir has two porous internal compartments interconnected with a third porous internal compartment.

Optionally, the three porous internal compartments can be replaced with one porous internal compartment having a cross section shaped like an alphabet letter, "U", i.e. the
20 three porous internal compartments can merge.

FIG. 49 is a schematic vertical cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 18.

FIG. 50 is a perspective view of the reservoir of FIG. 49.

FIG. 51 is a schematic horizontal cross-sectional view of the reservoir of FIG. 49 along line A-A.

FIG. 52 is a schematic vertical cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 20 having at least one porous internal compartment.

FIG. 53 is a schematic horizontal cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 52 along line A-A.

FIG. 54 is a schematic horizontal cross-sectional view of another embodiment of the liquid fuel reservoir of FIG. 52 along line A-A.

FIG. 55 is a schematic horizontal cross-sectional view of the liquid fuel reservoir of FIG. 52 along line B-B.

FIG. 56 is a schematic vertical cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 24 having two porous internal compartments.

FIG. 57 is a schematic perspective view of one of the embodiments of the liquid fuel reservoir of FIG. 40 having two porous internal compartments.

FIG. 58 is a schematic horizontal cross-sectional view of the liquid fuel reservoir of FIG. 57 along line A-A.

FIG. 59 is a schematic horizontal cross-sectional view of the liquid fuel reservoir of FIG. 57 along line B-B.

FIG. 60 is a schematic horizontal cross-sectional view of the liquid fuel reservoir of FIG. 57 along line C-C.

FIG. 61 is a schematic vertical cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 41 having a porous internal compartment.

FIG. 62 is a schematic perspective view of the liquid fuel reservoir of FIG. 61.

FIG. 63 is a schematic perspective view of one of the embodiments of the liquid fuel reservoir of FIG. 38 having two porous internal compartments.

FIG. 64A is a schematic vertical cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 18 containing an impurities scavenger in an outlet passageway.

FIG. 64B is a schematic vertical cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 18 containing an impurities scavenger in a filter cartridge connected to an outlet passageway.

FIG. 65 is a schematic vertical cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 20 containing an impurities scavenger in an outlet passageway.

FIG. 66 is a schematic vertical cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 21 containing an impurities scavenger in an outlet passageway.

FIG. 67 is a schematic vertical cross-sectional view of one of the embodiments of the liquid fuel reservoir of FIG. 41 containing an impurities scavenger in an outlet passageway.

Detailed Description of the Invention

In the invention, "wicking" means wicking by capillary action, i.e. moving a liquid by capillary forces. A "wicking structure" is a structure capable of wicking a liquid by capillary action, which liquid may be later released from the structure. The "wicking structure" comprises a wicking material capable of wicking the liquid by capillary action.

5 The wicking structure can be a porous member made of one or more polymers resistant to the liquid fuel. The wicking structure material can be selected from foams, bundled fibers, matted fibers, needled fibers, woven or nonwoven fibers, Porex and Porex like polymers, porous polymers or inorganic porous materials that can wick the liquid fuel. The wicking structure material preferably is selected from the group
10 consisting of foams, bundled fibers, woven or nonwoven fibers, Porex and porous polymers made by pressing polymer beads. More preferably, the wicking structure material is selected from polyurethane foams (preferably felted polyurethane foams, reticulated polyurethane foams, or felted reticulated polyurethane foams), melamine foams, polyvinyl alcohol foams, or nonwoven felts, woven fibers or bundles of fibers
15 made of polyamide such as nylon, polyethylene, polypropylene, polyester such as polyethylene terephthalate, cellulose, modified cellulose such as Rayon, polyacrylonitrile, and mixtures thereof that can wick the liquid fuel. Certain inorganic porous materials, such as sintered inorganic powders of silica or alumina, can also be used as the wicking structure material. Most preferably, the wicking structure material is
20 a polyurethane foam, e.g. felted polyurethane foam, reticulated polyurethane foam, or felted reticulated polyurethane foam.

The wicking structure material is preferably a polyurethane foam having a density in the range of about 0.5 to about 45 pounds per cubic foot, more preferably about 0.5 to about 25 pounds per cubic foot, even more preferably about 0.5 to about 15 pounds per cubic foot, most preferably about 0.5 to about 10 pounds per cubic foot, and pore sizes in the range of about 10 to about 200 pores per linear inch, preferably about 40 to about 200 pores per linear inch, and most preferably about 75 to about 200 pores per linear inch.

If a felted polyurethane foam, e.g. a felted reticulated polyurethane foam, is selected as the wicking structure material, such foam preferably should have a density in the range of about 1.5 to about 60 pounds per cubic foot and a compression ratio in the range of about 1.1 to about 30, more preferably a density in the range of about 3 to about 40 pounds per cubic foot and a compression ratio in the range of about 1.5 to about 20, and most preferably a density in the range of about 3 to about 10 pounds per cubic foot and a compression ratio in the range of about 3 to about 30. Felted foams of greater compression, however, may be used as the wicking structure materials.

A felted foam is produced by applying heat and pressure sufficient to compress the foam to a fraction of its original thickness. For a compression ratio of 30, the foam is permanently compressed to 1/30 of its original thickness. For a compression ratio of 2, the foam is permanently compressed to 1/2 of its original thickness. Typically, to create a felted foam, the foam is compressed for from 5 to 60 minutes and heated to temperatures from 350°F to 400°F. During the felting process, the cellular polymer strand network is crushed to a more unidirectional state, where the strands are oriented more in parallel. This is sometimes called an anisotropic cell structure.

A reticulated foam is produced by removing the cell windows from the cellular polymer structure, leaving a network of strands and thereby increasing the fluid

permeability of the resulting reticulated foam. Foams may be reticulated by *in situ*, chemical or thermal methods known to those of skill in foam production.

In the liquid fuel reservoir of the invention, the volume effectively occupied by the wicking structure is preferably minimized. One of the ways of minimizing the volume effectively occupied by the wicking structure is to minimize the external volume of the wicking structure by providing a wicking structure that extends to the extreme parts of the volume within the container, with the central portion of the volume within the container being substantially devoid of the wicking structure material. The central portion of the volume within the container can be made substantially devoid of the wicking structure material by making the wicking structure with no or only a minimal amount of wicking structure material in the central portion of the volume within the container. The "central portion of the volume within the container" is the inner 70%, preferably 80%, more preferably 90%, most preferably 95%, of the volume within the container. Alternatively, the central portion of the volume within the container can be made substantially devoid of the wicking structure material by perforating the wicking structure material. Preferably, the wicking structure material is perforated except in portions of the wicking structure material proximate the walls of the container or except a portion of the wicking structure material in a zone extending from the external surface of the wicking structure adjacent to a wall of the container to a depth of 20% (preferably 10%, and more preferably 5%) of the thickness of the wicking structure at that region, wherein the "thickness of the wicking structure at that region" is the length of a first imaginary line perpendicular to a second imaginary line tangential to the external surface of the wicking structure at that region, which first imaginary line starts at the external surface, extends through the wicking structure material and ends at where the first imaginary line meets an external surface on the opposite side of the wicking

structure. When the wicking structure material is perforated, at least a part of the wicking structure material is removed, and consequently the size of the perforation is larger than the nominal size of the pores in the wicking structure material.

One of the ways of minimizing the volume effectively occupied by the wicking structure is to perforate the wicking structure material. The size of the perforation is larger than the nominal size of the pores in the wicking structure material.

By minimizing the amount of the wicking structure material (either by perforating the wicking structure material or by making the central portion of the volume within the container substantially devoid of the wicking structure material), the amount of the liquid fuel that the liquid reservoir can deliver can be maximized because the amount of the liquid fuel that the liquid fuel reservoir can hold can be increased and the amount of the liquid fuel remaining in the wicking structure after all the deliverable liquid fuel is discharged from the liquid reservoir can be decreased. In this preferred embodiment of the liquid fuel reservoir, the volume within the container can have a rectangular or square cross section having eight corners and a square or rectangular shape viewed from the top, and the wicking structure is disposed at least at or proximate the eight corners. For instance, the wicking structure can have a configuration of a square or rectangular sheet with a plurality of perforations, a square or rectangular rim, or a configuration shaped like an alphabet letter "E", "H", "K", "M", "N", or "X". The configuration shaped like the alphabet letter "H" includes a configuration shaped like an uppercase alphabet letter "I" because the alphabet letter "H" is equivalent to the uppercase alphabet letter "I" turned 90°. Similarly, the configuration shaped like the alphabet letter "N" includes a configuration shaped like an alphabet letter "Z".

Alternatively, the container can have a curved wall so that the volume within the container can have a round or oval cross section when viewed from above, wherein the

wicking structure can be disposed at least as a circular or oval ring along the curved edge of the volume within the container.

Within the scope of the invention, one of the ways of minimizing the external volume of the wicking structure in a liquid fuel reservoir is to have the wicking structure comprising a sheet or layer of the wicking structure material disposed adjacent to all, or
5 all but one, of the lateral walls of the container. In some of the embodiments of the liquid fuel reservoir within this aspect of the invention, the liquid fuel reservoir comprises

(a) a container having 5, 6, 7, 8, 9 or 10 walls: a first and second end walls and 3,
4, 5, 6, 7 or 8 lateral walls, respectively, wherein the first and second end walls are
10 opposite to each other and each of the lateral walls is connected to the first and second end walls and to two adjacent lateral walls, wherein the container has a triangular, quadrilateral (preferably square, rectangular, trapezoidal or parallelogram; more preferably, square or rectangular), pentagonal, hexagonal, heptagonal or octagonal cross section, respectively, formed by the lateral walls, said walls defining a volume for
15 holding a liquid fuel for a liquid fuel cell or microformer; wherein the container has an outlet passageway through one of the walls suitable for the exit of the liquid fuel to a location exterior to the container, said outlet passageway optionally having a one-way valve that prevents the backflow of the liquid fuel into the container, and the container optionally having an inlet which optionally has a one-way valve allowing the flow of a
20 gas or the liquid fuel into the container; and

(b) a wicking structure disposed within the volume of the container, wherein the wicking structure comprises a sheet or layer of a wicking structure material which can wick the liquid fuel and wherein the liquid fuel wicked into the wicking structure material can subsequently be discharged out of or released from the wicking structure material,
25 and wherein the sheet or layer is disposed along or adjacent to all, or preferably all but

one, of the lateral walls of the container, and wherein an edge of the sheet or layer is proximate (or in contact with) a portion of the first end wall and an opposite edge of the sheet or layer is proximate (or in contact with) a portion of the second end wall.

Within the aspect of the invention in which the liquid fuel reservoir has the external volume of the wicking structure minimized, in some of the embodiments, the container has 3 walls: a first and second end walls connected by a curved lateral wall, and a circular, oval or elliptic cross section formed by the curved lateral wall, wherein the wicking structure comprises a sheet or layer of the wicking structure material disposed along or adjacent to the curved lateral wall of the container, and wherein an edge of the sheet or layer is proximate or in contact with the first end wall and an opposite edge of the sheet or layer is proximate or in contact with the second end wall.

For fuel reservoirs intended for use in applications where the container orientation is expected to change during use, the container having a proximal end and a distal end with the proximal end being where the outlet passageway is disposed and the distal end being the end remote to the outlet passageway, the wicking structure preferably contacts at least one portion of the inner surface of the distal end of the container, and the wicking structure communicates with the outlet passageway. More preferably, the wicking structure contacts at least one portion of the inner surface of the distal end of the container and at least one portion, even more preferably a substantial portion, of the inner surface of a sidewall of the container, and the wicking structure also communicates with the outlet passageway. Most preferably, the wicking structure contacts at least one portion of the inner surface of the distal end of the container, at least one portion, even more preferably a substantial portion, of the inner surface of a sidewall of the container, and at least one portion of the inner surface of the proximal end of the container, and the wicking structure also communicates with the outlet

passageway. Especially preferable is for the wicking structure to contact at least one portion of the inner surface of the distal end of the container, at least one portion (preferably a substantial portion) of the inner surface of a sidewall of the container, at least one portion of the inner surface of the proximal end of the container, and every
5 extremity of the container volume, wherein the wicking structure communicates with the outlet passageway, so that the wicking structure is in fluid communication with every extremity of the container.

In an embodiment of the liquid fuel reservoir of the invention, a retainer is provided within the container. The retainer holds the wicking structure preferably in
10 contact with at least one portion of the interior surface of the container having a proximal end and a distal end, wherein the outlet passageway is formed through the proximal end and the distal end is the end remote to the outlet passageway. The retainer holds the wicking structure more preferably in contact with at least one portion of the inner surface of the distal end of the container and with at least one portion of an
15 inner surface of a sidewall of the container. Also more preferably, the retainer holds the wicking structure in contact with at least one portion of the inner surface of the distal end of the container and at least one portion (preferably that portion adjacent the outlet passageway) of inner surface of the proximal end of the container. Most preferably, the retainer holds the wicking structure in contact with at least one portion of the inner
20 surface of the distal end of the container, at least one portion of the inner surface of a sidewall of the container, and at least one portion (preferably that portion adjacent the outlet passageway) of the inner surface of the proximal end of the container.

When the container has the retainer inside, the wicking structure is preferably mounted over at least a portion of the retainer, and the retainer is attached to a cap that
25 engages the distal end of the container. With such an embodiment, the wicking

structure so mounted over the retainer is slidably insertable into and optionally removable from the container.

In an alternative embodiment, the retainer comprises a connector extending from the inner surface of the distal end or from the inner sidewall surface of the container.

5 The connector grips a portion of the wicking structure material to hold it in position within the container. As an example, the connector is a clamp, a combination of clamps, a toothed edge, or a VELCRO nub, each of which grasps a portion of the wicking structure material. For other embodiments, the wicking structure may be connected to the container by heat sealing, ultrasonic welding, molded in place by
10 inserting the wicking material in an injection molding tool in order to avoid using any adhesive, or adhesive.

When the liquid fuel reservoir is provided with a retainer, the retainer preferably has a perforate structure to permit the liquid fuel to flow through the retainer structure and to minimize the effective volume occupied by the retainer in order to increase the
15 amount of the liquid fuel that the fuel reservoir can hold. The effective volume of the retainer is the solid volume of the retainer, i.e. the volume occupied by the solid material of the retainer. In other words, the solid volume of the retainer is the total or external volume of the retainer minus the void volume of the retainer. The "void volume of the retainer" is the collective volume of any perforations of the retainer. More preferably,
20 the retainer is of a material in the form of a screen, slotted sheet, or perforated sheet, each of which made of an appropriate fuel resistant material. For methanol as the liquid fuel, such fuel resistant materials include polypropylene, polyethylene, polyvinyl chloride, and the like.

While the wicking structure and the retainer, if present, can be sized to fill a
25 substantial portion of the volume of the container, improved results can be achieved

where a greater portion of the container volume is filled by the liquid fuel and a lesser portion of the container volume is taken up by the wicking structure and the optional retainer. It is desirable to minimize the volume effectively occupied by any internal structure(s) of the fuel reservoir in order to maximize the amount of liquid fuel that can be held in the container, and permit the liquid fuel in the container to be discharged therefrom in any orientation of the container, and at substantially any stage of liquid fuel depletion in the container with a minimum amount of retained liquid fuel. The internal structure(s) of the fuel reservoir includes the wicking structure in the absence of the retainer, or the wicking structure and the retainer, if present. Thus, it is desirable to minimize the sum of the solid volume of the wicking structure and the solid volume of the retainer, if present. The "solid volume of the wicking structure" is the volume occupied by the solid material of the wicking structure. In other words, the "solid volume of the wicking structure" is the external volume of the wicking structure minus its void volume. The "void volume of the wicking structure" is the total volume of all pores, perforations or interstices in the wicking structure. The "external volume of the wicking structure" is the volume of the wicking structure as defined by the external surface(s) of the wicking structure, so the "external volume of the wicking structure" is the sum of the solid volume and the total volume of all the pores or perforations in the wicking structure. In the event that the void volume of the wicking structure or the retainer is not known, or if a simpler, alternative approach is desired, the sum of the external volume of the wicking structure and the external volume of the retainer, if present, can be minimized in order to increase the amount of liquid fuel that can be held in the container.

Consequently, it is desirable to make the wicking structure comparatively thin. The volume taken up by the wicking structure can be further reduced by forming voids

in the wicking structure, such as by perforating or slotting the wicking structure, so long as the wicking function is not impaired.

In an embodiment aimed at increasing the amount of liquid fuel that the fuel reservoir can hold, the solid volume of the wicking structure is preferably no more than 50% (e.g. less than 50%, such as no more than 45%), more preferably no more than 40% (e.g. no more than 25%), even more preferably less than 20% (e.g. no more than 12.5%), much more preferably less than 10% (e.g. no more than 5%), even much more preferably no more than 3%, and most preferably about 1%, of the volume within the container. The void volume of the wicking structure is preferably at least about 50%, more preferably about 60% to 98% (e.g. about 65% to 98%), even more preferably about 70% to 98% (e.g. about 70% to 85%), and most preferably about 80% to 98% (e.g. about 95%), of the external volume of the wicking structure. The solid volume of the retainer, if present, is preferably no more than about 15% (e.g. no more than about 12%), more preferably less than about 10% (e.g. no more than about 7%), much more preferably less than about 5% (e.g. no more than about 3%, such as about 1%) and most preferably less than about 1% (e.g. from about 0.5% to about 0.05%, such as about 0.5%, about 0.25%, about 0.1% or about 0.05%), of the volume within the container.

As an alternative, to increase the amount of the liquid fuel that the fuel reservoir can hold, the external volume of the wicking structure is preferably no more than about 65%, more preferably no more than about 50%, even more preferably no more than about 25%, and most preferably no more than about 10%, of the volume within the container. The external volume of the retainer, if present, is preferably no more than about 20%, more preferably no more than about 10%, even more preferably no more

than about 5%, and most preferably no more than about 1%, of the volume within the container.

Referring to the drawings, some of the preferred embodiments of the invention are described below.

5 Referring first to FIG. 1, a fuel reservoir **10** is shown in combination with a pump **12** that directs liquid fuel such as methanol to a fuel cell **14** (indicated symbolically as a voltage source "V"), which is a source for power to a portable electronic device, such as a cellular telephone **14**. The pump **12** communicates with an outlet passageway **24** of the fuel reservoir **10** to pump the liquid fuel out of the container **20** through the outlet
10 passageway (see FIG. 2 and 3). An inlet **26** having a one-way valve (not shown) is provided to the container **20** to permit gas flow into the volume of the container **20**. In one of the embodiments, the container **20** is filled with 6 ml. of an aqueous fuel solution containing up to 100% methanol, preferably about 5% methanol. A pump **12** acts on the outlet tube **24** and draws liquid fuel **22** from the wicking structure **32** through the
15 outlet tube **24**. Only a slight vacuum needs to be placed on the outlet tube **24** to draw the fuel mixture out of the container.

As shown in greater detail in FIGs. 2-5, the fuel reservoir **10** has a container **20** formed as a case or cartridge that defines an internal volume holding a liquid fuel mixture **22**. An outlet tube **24** extends into the container **20** through a proximal surface
20 **38** and the outlet tube **24** communicates between the internal volume of the container **20** and the exterior of the container. An inlet tube **26** also extends into the container **20** through cover **38**. The inlet tube **26** includes a one-way valve (not shown) so as to prevent liquid from flowing out of the container **20**. Such a one-way valve may be placed on board the cartridge, or optionally on board the fuel cell. Alternatively, the inlet
25 port may be connected to a waste stream from the fuel cell. Preferably, the gas

entering the internal volume of the container **20** is air, but may also be an inert gas, such as nitrogen.

The materials forming the container **20** and tubes **24**, **26** have to be fuel resistant. Where the fuel is methanol, the fuel resistant materials can be polypropylene, polyethylene, polyvinyl chloride and other appropriate materials. Where the fuel reservoir **10** is intended for use with a reformer, materials resistant to hydrocarbons should be used. Ideally, the tubes/vents **24**, **26** will be injection molded together with the container **20** in one molding step.

A wicking structure **32** is provided within the volume of the container **20**. The wicking structure **32** is mounted over a retainer **34**. The retainer **34** is formed from a perforated sheet into a bent "U" shape that conforms to the shape of the internal side walls **36** and internal proximal end wall **38** of the container **20**. The end portions **42** of the retainer **34** connect to the end cap **44** that closes the distal end of the container **20** when the container is filled with liquid fuel. When the end cap **44** closes the distal end of the container **20**, the end cap **44** can be considered as a part, i.e. the distal end wall, of the container. Holes **46** through the thickness of the retainer **34** permit liquid fuel to contact the wicking structure **32**. The retainer **34** urges and holds the wicking structure **32** into contact with the internal side walls and the internal proximal wall of the container, as well as an internal surface of the distal end wall **44** of the container. The wicking structure **32** thus is in communication with the internal opening of the outlet tube **24** of the container **20**.

The cap **44** preferably also is made from a fuel compatible material, which generally will be the same as the material selected for the remainder of the container. In a preferred embodiment, the cap **44** is ultrasonically welded to the container **20** to create a fluid tight connection between the cap **44** and container **20**.

In the embodiment shown in FIGs. 2-5, the wicking structure **34** is mounted on the retainer **32** and the retainer **32** is connected to the cap **44**. As best shown in FIG. 2, when the cap **44** is removed from the container **20**, the retainer **34** and wicking structure **32** are slidably removable from the container **20**. Conversely, when the cap **44** is re-
5 attached to the container **20**, the retainer **34** and wicking structure **32** are slidably engageable with the container **20**. The fuel reservoir or package is thus assembled by mounting the wicking structure onto the retainer, connecting the retainer to the cap and slidably engaging the wicking structure, retainer and cap with the container to place the wicking structure in communication with the outlet tube and distal portion(s) of the
10 container volume. As stated, the cap **44** then can be sealingly connected to the container **20**, such as by ultrasonic welding.

The wicking structure **32** is formed as a thin sheet or layer. Liquid fuel can wick into the wicking structure **32**. The fuel reservoir **10** works best when the wicking structure **32** defines a path to direct the liquid fuel from the most distal portions of the
15 container volume to the internal opening of the outlet tube **24**. The fuel reservoir **10** may be used in all possible spatial orientations so long as the wicking structure **32** provides such fluid communication between the distal portions and the outlet tube **24**. While it is possible to have a wicking structure **32** fill all or substantially all of the internal volume of the container **20**, lesser amounts of wicking structure material may be used to
20 direct and help meter or deliver the liquid fuel to the outlet tube **24**. Thus, as shown in FIGs. 3 and 4, the wicking structure **32** extends to the distal end surface defining the internal fluid holding volume of the container, but this wicking structure **32** does not contact all internal surfaces of the container.

Referring back to FIG. 1, the connection between outlet tube **24** and the pump **12**
25 may be a quick disconnection, so that the outlet tube **24** may be capped during storage

and shipment before the fuel reservoir **10** is installed for use with a portable electronic device. A cap is not shown in FIG. 1, but the distal end of the container can be of any suitable construction that will maintain the liquid fuel within the container.

In an example of the embodiment shown in FIGs. 2 to 5, the wicking structure **32** is a felted polyurethane foam shaped as a thin sheet mounted over the retainer **34**. The wicking structure can be a sheet of about 0.4 mm to about 2.5 mm thick. Preferably, the sheet of wicking material is between about 0.8 mm (1/32 inch) and about 1.6 mm (1/16 inch) thick.

The foam was produced with the following mix:

Arcol 3020 polyol (from Bayer Corp.)	100 parts
Water	4.7
Dabco NEM (available from Air Products)	1.0
A-1 (available for OSi Specialties/Crompton)	0.1
Dabco T-9 (available from Air Products)	0.17
L-620 (available from OSi Specialities/Crompton)	1.3

After mixing for 60 seconds and allowed to degas for 30 seconds, 60 parts of toluene diisocyanate were added. This mixture was mixed for 10 seconds and then placed in a 15" x 15" x 5" box to rise and cure for 24 hours. The resulting foam had a density of 1.4 pounds per cubic foot and a pore size of 85 pores per linear inch. The foam was thermally reticulated, then felted by applying heat (360°F) and pressure sufficient to compress the foam to 1/5 of its original thickness (*i.e.*, compression ratio = 5). The heat and compressive pressure were applied for about 5 minutes to a thickness of 1/32 inch (0.8mm). The resulting felted foam had a density of 7.0 pounds per cubic foot. When this felted foam was installed in a liquid fuel reservoir **10** such as shown in FIGs. 2-5, the liquid fuel reservoir had a 90% or greater fuel delivery efficiency, which means that

90% or more of the liquid fuel that was loaded into fuel-empty container could be discharged from the container and directed to a fuel cell used to power a portable electronic device at any spatial orientation of the fuel reservoir.

The retainer **34** preferably is formed from a material or a composite of materials that will not degrade when exposed to liquid fuels intended to be delivered via the liquid fuel reservoir. The preferred materials for the retainer **34** comprise those materials suitable for forming the container **20**. In a most preferred embodiment, the retainer **34** is injection molded plastic, but it may also be formed as a screen or other slotted or perforated structure so long as it is able to retain the wicking structure **32** in place within the container **20**.

The container of the fuel reservoir may take various shapes with various regular or irregular cross sections. Examples of regular cross sectional shapes include circular, oval, elliptic, rectangular, square, parallelogram, trapezoidal or triangular shapes. Oblong or other eccentric shapes as designed for installation in portable electronic devices are also within the scope of this invention. One preferred container shape is a generally cylindrical cartridge comparable in size and shape to disposable dry cell batteries, or other known battery cartridge shapes. Alternatively, in addition to the rectangular cross section of FIGs. 2-5, the container **20** is formed with a circular cross section (as shown in FIGs. 6 and 7), and a square cross section (as shown in FIGs. 8-10).

Referring next to FIGs. 6 and 7, the container **60** is formed as a cylinder, with a circular cross section. As with the embodiment shown in FIGs. 2-5, the fuel reservoir includes a wicking structure **62** and a retainer **64** that holds the wicking structure **62** in place within the volume of the container **60**. The wicking structure **62** provides a path of liquid communication between the distal portions of the container **60** and the outlet tube

66. An inlet tube **68** having a one-way valve (not shown) that permits the entry of a gas into the container and prevents the exit of any liquid fuel is also provided. The wicking structure **62** is formed from a woven material, and the wicking structure is held in contact with the entire internal sidewall of the container **60**.

5 Referring to FIGs. 8 and 9, the container **80** has a cubic shape with a square cross section. The wicking structure **82** is held in place by retainer **84**. The wicking structure **82** is constructed of foam and provides a path of liquid communication between the distal portions of the container **80** and the outlet tube **86**. In this embodiment, the retainer **84** is formed as a perforated sheet that holds the wicking
10 structure **82** in contact with the inner side walls and inner proximal surface of the container **80**, as well as with portions of the inner distal surface of the container at the four distal corners. The end cap **88** forming the distal end of the container may, but need not, be removable.

FIGs. 10 and 11 show an alternative embodiment using a different retainer and
15 wicking structure. The container **100** comprises a generally cubic shape with a square cross section. The container **100** defines an internal volume for storing liquid fuel. L-shaped mounting clamps **102** extend from each corner of the distal internal surface of the container **100**. A wicking structure **104** is formed as a central sheet **106** with four downwardly depending legs **108**. The legs **108** extend toward the distal end internal
20 surface of the container **100**. The legs terminate at end portions that engage the L-shaped mounting clamps **102** at pins **103**. In this embodiment, the mounting clamps **102** form the retainer to keep the end portions of the legs of the wicking structure **104** in position within the volume of the container **100**. Fuel outlet tube **110** and inlet tube **112** extend into the container **100** at the proximal internal surface. The inlet tube **112** has a
25 one-way valve (not shown) that permits the entry of a gas into the container. A backing

plate **107** is connected to the sidewall of the container **100** with several supports **109** to hold the wicking structure **104** adjacent to the proximal internal surface of the container **100** and in fuel communication with the outlet tube **110**. In this embodiment, the wicking structure **104** is positioned so as to direct liquid from the distal corners of the internal volume of the container **100** to the outlet tube **110**. Even though the wicking structure does not contact completely any one of the internal sidewalls of the container, the wicking structure functions to direct liquid fuel to the outlet tube so that such fuel may be metered or pumped out of the fuel reservoir. Thus, in any orientation of the container **100**, and at any stage of liquid fuel depletion within the container **100**, the liquid fuel in the container will contact, or may be placed in contact with, wicking structure **104**, either at central sheet **106** directly or through legs **108** to central sheet **106**. Although not shown, alternatively the wicking structure can be modified by replacing the central sheet **106** with two linear members joined at the center to form a cross, wherein the ends of the two members are connected to the upper ends of the downwardly depending legs, and wherein the liquid fuel outlet tube extends through the proximal wall of the container to maintain fluid communication with the wicking structure by communicating with one of the two members, preferably with the junction of the two members, i.e. at the center of the cross.

Referring next to FIG. 12, an alternative structure for a liquid fuel reservoir has a container **120** defining an internal volume for holding a liquid fuel mixture **22**. An outlet tube **124** extends into the container **120** through a first sidewall surface **122**. The outlet tube communicates between the internal volume of the container **120** and the outside of the container. An inlet tube **126** also extends into the container **120** through first sidewall surface **122**. The inlet tube includes a one-way valve (not shown) that permits the entry of a gas but prevents liquid from flowing out of the container **120**. In the

embodiment of FIG. 12, the outlet tube **124** and inlet tube **126** are disposed along a sidewall of the container **120**, rather than along the proximal end wall as shown in earlier embodiments. An embodiment identical to the embodiment of FIG. 12 except for the positions of the inlet and outlet tubes is shown in FIG. 13. The outlet tube **124a** is
5 disposed along a sidewall of the container **120a**, whereas the inlet tube **126a** is disposed along a different sidewall in FIG. 13. Such alternative orientations for the inlet and outlet tubes may provide greater flexibility when the liquid fuel reservoir is used to power a portable electronic device.

In FIGs. 12 and 13, a wicking structure **130** is provided within the volume of the
10 container **120**. The wicking structure **130** is formed as an internal sleeve defining an inner core that is void of wicking material and having outer surfaces that contact the internal sidewalls of the container **120**. The wicking structure **130** is held in contact with the internal sidewalls of the container by a retainer **128** that has perforations or
channels **136** extending therethrough. The wicking structure **130** contacts the distal **132**
15 and proximal **134** end walls of the container **120** at the corners thereof where these end walls join the sidewalls. However, the wicking structure **130** does not cover the entire internal surfaces of such distal **132** and proximal **134** end walls. The wicking structure is designed to contact such corners so that the liquid fuel mixture may be drawn into the
wicking structure by capillary action independent of either (a) the orientation of the liquid
20 fuel reservoir; or (b) the extent to which the container volume has been drained of the liquid fuel mixture. The wicking structure thus contacts the portions of the container volume most distant from the connection to the outlet tube and associated pump. Moreover, by reducing the amount of the wicking material used to form the wicking structure, less internal volume of the container is filled by the wicking material. Thus,
25 because a portion of the liquid fuel remains within the wicking material as the container

volume is emptied of liquid fuel, this embodiment can increase the efficiency of fuel delivery as compared to liquid fuel reservoirs where more wicking material is inserted into the volume of the container.

FIG. 14 shows yet another embodiment of a liquid fuel reservoir according to the invention in which a container **140** defines an internal volume for holding a liquid fuel mixture **22**. An outlet tube **144** extends into the container **140** through a proximal end wall surface **148**. The outlet tube communicates between the internal volume of the container **140** and the outside of the container. An inlet tube **146** extends into the container **140** through a distal end wall surface **150**. The inlet tube **146** includes a one-way valve (not shown) so as to prevent liquid from flowing out of the container **140**. In the embodiment of FIG. 14, the outlet tube **144** and inlet tube **146** are disposed at opposite ends of the container **140**, rather than both being disposed from the proximal end wall or side walls as shown in earlier embodiments.

A wicking structure **154** is provided within the volume of the container **140**. The wicking structure **154** is formed with an I-beam shape having flanges **162** disposed at each end of a column **160**. The flanges **162** are held in contact with the internal proximal end wall **148** and internal distal end wall **150**, respectively, with retainers **156** having perforations or holes **158** therethrough. As shown in FIG. 14, the column **160** is disposed centrally with respect to flanges **162** to form the I-beam shape. Alternatively, the column portion could connect the flange portions at other orientations, such as disposed along the internal side wall or disposed at a diagonal. The flanges **162** of the wicking structure **154** shown in FIG. 14 contact the corners of the internal volume of the container **140** where the sidewalls **142** meet the end walls **148**, **150**. The wicking structure is designed to contact such corners so that liquid fuel may be drawn into the wicking structure by capillary action independent of either (a) the orientation of the liquid

fuel reservoir; or (b) the extent to which the container volume has been drained of the liquid fuel mixture. This configuration locates wicking material in the most distant crevices or extremities of the container, and by virtue of the capillarity of the wicking material, puts the distant crevices into fluid communication with the outlet tube and associated pump. Moreover, by reducing the amount of the wicking material used to form the wicking structure, less internal volume of the container is filled by wicking material. Thus, because a portion of the liquid fuel remains within the wicking material as the container volume is emptied of the liquid fuel, this embodiment can increase the efficiency of fuel delivery as compared to liquid fuel reservoirs where more wicking material is inserted into the volume of the container.

The amount of wicking material that is used to form a wicking structure for use in a liquid fuel reservoir according to the invention also can be minimized by removing or eliminating portions of the wicking material without adversely impacting the structural integrity or wicking ability of the wicking material. For example, where a foam is selected for the wicking material, the foam may be perforated by piercing or puncturing the foam to form holes therethrough. As shown in FIG. 15, a wicking structure **130b** formed as a sleeve suitable for use in the embodiments of the invention shown in FIGs. 12 and 13, has been punctured to form holes **166** through the thickness of the foam material forming the wicking structure. Such holes can be provided in a regular or irregular pattern, although a regular grid-like pattern is shown in FIG. 15. Moreover, holes may be provided in the side walls of the wicking structure, although holes **166** are shown only through the top and bottom walls of the wicking structure **130b**. Sufficient foam material is left in the wicking structure **130b** so that such material will wick and deliver the liquid fuel to the outlet tube when pumping force is applied to the outlet.

A wicking structure with acceptable capillary or wicking characteristics but with lesser wicking material may also be formed from expanded foam or other sheet form wicking material. Referring to FIGs. 16 and 17, an expanded foam material is made by slitting through the thickness of a foam sheet **170** to form a series of slits **172** (FIG. 16).
5 The foam sheet **170** is then stretched or pulled in the direction of arrows **176** (FIG. 17) to open the slits **172** to form open elongated slots **178**. A wicking structure can then be formed from the expanded foam sheet **170a**.

FIGs. 18-37 are schematic diagrams of a number of embodiments of the liquid fuel reservoir of the invention in which the external volume of the wicking structure is minimized to increase the amount of the liquid fuel that the reservoir can hold. For
10 illustration purposes, these liquid fuel reservoirs all have a rectangular shape with a rectangular cross section in FIGs. 18-37. However, liquid fuel reservoirs of similar construction having a different shape, e.g. a rectangular shape with a square cross section or a cubical shape with a square cross section or irregular shapes, are also
15 included within the scope of the invention.

As shown in FIG. 18, a liquid fuel reservoir **200** has a container **242** that defines a volume **246** for holding a liquid fuel mixture. A wicking structure **244** in the shape of two vertical posts linked to a crossbar at the top is provided along the inside top surface and inside side surfaces of the container **242**. An outlet tube **248** and inlet tube **250**
20 extend through a top wall of the container. The outlet tube **248** is in liquid communication with the wicking structure **244**. The inlet tube **250** has a one-way valve (**251**) that permits the entry of a gas into the container and prevents the outflow of any liquid. FIG. 19 is a perspective view of the liquid fuel reservoir of FIG. 18. The wicking structure **244** extends substantially from the front to the back of the volume **246** inside
25 the container **242**, for example, by directly contacting the front and back walls of the

container or by almost contacting the front and back walls (FIG. 19). With such a design, every extremity of the volume inside the container is in liquid communication with the outlet tube **248** at least through the wicking structure **244** via capillarity. This allows any liquid fuel inside the container to be delivered to the exterior of the container via a liquid delivery means, such as a pump, connected to the outlet tube **248** regardless of the amount of the liquid fuel that has been discharged from the liquid fuel reservoir and independent of the orientation of the liquid fuel reservoir.

FIGs. 20 and 21 show two other embodiments of the liquid fuel reservoir of the invention having the external volume of the wicking structure minimized. The liquid fuel reservoir **202**, **204** includes a container **252**, **262** defining a volume **256**, **266**, a wicking structure **254**, **264** in the shape of a rectangular rim, and an outlet tube **258**, **268** and an inlet tube **260**, **270** extending through a top wall of the container. The outlet tube **258**, **268** is in liquid communication with the wicking structure **254**, **264**. The inlet tube **260**, **270** contains a one-way valve (**261**, **271**) that permits the inflow of a gas and prevents the outflow of any liquid. The wicking structure **254**, **264** is in contact with substantially the entire internal surfaces of the top, side and bottom walls of the container **252**, **262**. Although not shown, the wicking structure **254**, **264** extends substantially from the front to the back of the volume of the container **252**, **262** by contacting portions of the internal surfaces of the front and back walls of the container along or proximate the junctions of the front or back walls with the top, side or bottom walls. All the extremities of the volume inside the container are in liquid communication with the wicking structure via at least capillarity. The embodiments of FIGs. 20 and 21 differ only in the location of the outlet tube, with the outlet tube **258** disposed near the center of the top wall and the outlet tube **268** disposed near a corner.

FIGs. 22 and 23 show two other embodiments of the liquid fuel reservoir of the invention having the external volume of the wicking structure minimized. The liquid fuel reservoir **206, 208** includes a container **272, 282** defining a volume **276, 286**, a wicking structure **274, 284** in the shape of an alphabet letter "H", an outlet tube **278, 288** extending through a wall of the container, and an inlet tube **280, 290** extending through the same or a different wall of the container. The outlet tube **278, 288** is in liquid communication with the wicking structure **274, 284**. The inlet tube **280, 290** contains a one-way valve (**281, 291**) that permits the inflow of a gas and prevents the outflow of any liquid. The wicking structure **274, 284** is in contact with substantially the entire internal side surface of the container **272, 282** and two portions each of the internal top and bottom surfaces of the container **272, 282** at or proximate the corners. Although not shown, the wicking structure **274, 284** extends substantially from the front to the back of the volume of the container **272, 282**. All the extremities of the volume inside the container are in liquid communication with the wicking structure via at least capillarity. The embodiments of FIGs. 22 and 23 differ only in the location of the outlet tube with the outlet tube **278** extending through a side wall and the outlet tube **288** extending through a top wall of the container.

FIGs. 24 and 25 show two other embodiments of the liquid fuel reservoir of the invention having the external volume of the wicking structure minimized. The liquid fuel reservoir **210, 212** includes a container **292, 302** defining a volume **296, 306**, a wicking structure **294, 304** in the shape of an alphabet letter "X", an outlet tube **298, 308** extending through a wall of the container, and an inlet tube **300, 310** extending through the same or a different wall of the container. The outlet tube **298, 308** is in liquid communication with the wicking structure **294, 304**. The inlet tube **300, 310** contains a one-way valve (**301, 311**) that permits the inflow of a gas and prevents the outflow of a

liquid. The wicking structure **294, 304** is in contact with portions of the internal surfaces of the container **292, 302** at or proximate the corners. Although not shown, the wicking structure **294, 304** extends substantially from the front to the back of the volume of the container **292, 302**. All the extremities of the volume inside the container are in liquid communication with the wicking structure via at least capillarity. The embodiments of FIGs. 24 and 25 differ only in the location of the outlet tube with the outlet tube **298** extending through a side wall and the outlet tube **308** extending through a top wall of the container.

FIGs. 26 and 27 show two other embodiments of the liquid fuel reservoir of the invention having the external volume of the wicking structure minimized. The liquid fuel reservoir **214, 216** includes a container **312, 322** defining a volume **316, 326**, a wicking structure **314, 324** in the shape of an alphabet letter "N", an outlet tube **318, 328** extending through a wall of the container, and an inlet tube **320, 330** extending through the same or a different wall of the container. The outlet tube **318, 328** is in liquid communication with the wicking structure **314, 324**. The inlet tube **320, 330** contains a one-way valve (**321, 331**) that permits the inflow of a gas and prevents the outflow of any liquid. The wicking structure **314, 324** is in contact with substantially the entire internal side surface of the container **312, 322** and two portions each of the internal top and bottom surfaces of the container **312, 322** at or proximate the corners. Although not shown, the wicking structure **314, 324** extends substantially from the front to the back of the volume of the container **312, 322**. All the extremities of the volume inside the container are in liquid communication with the wicking structure via at least capillarity. The embodiments of FIGs. 26 and 27 differ only in the location of the outlet tube with the outlet tube **318** extending through a top wall and the outlet tube **328** extending through a side wall of the container.

FIG. 28 illustrates another embodiment of the liquid fuel reservoir of the invention having the external volume of the wicking structure minimized. The liquid fuel reservoir **218** includes a container **332** defining a volume **336**, a wicking structure **334** in the shape of an inverted alphabet letter "M", an outlet tube **338** and an inlet tube **340** extending through a top wall of the container. The outlet tube **338** is in liquid communication with the wicking structure **334**. The inlet tube **340** contains a one-way valve (**341**) that permits the inflow of a gas and prevents the outflow of any liquid. The wicking structure **334** is in contact with substantially the entire internal side surface of the container **332** and two portions each of the internal top and bottom surfaces of the container **332** at or proximate the corners. Although not shown, the wicking structure **334** extends substantially from the front to the back of the volume of the container **332**. All the extremities of the volume inside the container are in liquid communication with the wicking structure via at least capillarity.

FIGs. 29 and 30 show two other embodiments of the liquid fuel reservoir of the invention having the external volume of the wicking structure minimized. The liquid fuel reservoir **220, 222** includes a container **342, 352** defining a volume **346, 356**, a wicking structure **344, 354** in the shape of an alphabet letter "K", an outlet tube **348, 358** extending through a wall of the container, and an inlet tube **350, 360** extending through the same or a different wall of the container. The outlet tube **348, 358** is in liquid communication with the wicking structure **344, 354**. The inlet tube **350, 360** contains a one-way valve (**351, 361**) that permits the inflow of a gas and prevents the outflow of any liquid. The wicking structure **344, 354** is in contact with substantially an entire internal surface of a side wall of the container **342, 352**, the internal surfaces of a portion of the other side wall and a portion of the top wall at or proximate where the other side wall and top wall meet, and the internal surfaces of a portion of the other side

5 wall and a portion of the bottom wall at or proximate where the other side wall and bottom wall meet. Although not shown, the wicking structure **344, 354** extends substantially from the front to the back of the volume of the container **342, 352**. All the extremities of the volume inside the container are in liquid communication with the wicking structure via at least capillarity. The embodiments of FIGs. 29 and 30 differ only in the location of the outlet tube with the outlet tube **348** extending through a side wall and the outlet tube **358** extending through a top wall of the container. The embodiment of FIG. 29 or 30 can be modified by having the wicking structure turned 90°, so that the wicking structure resembles the alphabet letter “K” turned 90° when viewed from the front. In other words, the vertical member of the wicking structure that contacts substantially the entire inner surface of a side wall of the container in FIG. 29 or 30 becomes a horizontal member contacting substantially the entire inner surface of a top wall of the container and the wicking structure further has two slanted members being connected to the horizontal member at a location proximate the center of the horizontal member and extending to contact portions of the inner surfaces of the two side walls and a bottom wall proximate the corners opposite the top wall, i.e. the corners formed by the two side walls and the bottom wall of the container. Alternatively, these embodiments have the wicking structure in the shape of the alphabet letter “K” or “K” turned 90° can be modified by having two slant members not connected to each other, wherein the two slant members are still connected to the vertical or horizontal member, such that the wicking structure is in the shape of a symbol “π” or “π” turned 90° when viewed from the front. In these modified embodiments, the liquid fuel outlet tube should extend through the wall that the vertical or horizontal member of the wicking structure contacts in its substantial entirety, so that the liquid fuel outlet tube communicates with the vertical or horizontal member of the wicking structure. Although not shown, these

modified embodiments of the embodiment according FIG. 29 or 30 are within the scope of the present invention.

FIGs. 31 and 32 show two other embodiments of the liquid fuel reservoir of the invention having the external volume of the wicking structure minimized. The liquid fuel reservoir **224, 226** includes a container **362, 372** defining a volume **366, 376**, a wicking structure **364, 374** in the shape of an alphabet letter "E", an outlet tube **368, 378** extending through a wall of the container, and an inlet tube **370, 380** extending through the same or a different wall of the container. The outlet tube **368, 378** is in liquid communication with the wicking structure **364, 374**. The inlet tube **370, 380** contains a one-way valve (**371, 381**) that permits the inflow of a gas and prevents the outflow of a liquid. The wicking structure **364, 374** is in contact with substantially the entire internal surfaces of a side wall, top wall and bottom wall of the container **362, 372**, a portion of the internal surface of the other side wall at or proximate where the other side wall and top wall meet, a portion of the internal surface of the other side wall at or proximate where the other side wall and bottom wall meet, and another portion of the internal surface of the other side wall. Although not shown, the wicking structure **364, 374** extends substantially from the front to the back of the volume of the container **362, 372**. All the extremities of the volume inside the container are in liquid communication with the wicking structure via at least capillarity. The embodiments of FIGs. 31 and 32 differ only in the location of the outlet tube with the outlet tube **368** extending through a side wall and the outlet tube **378** extending through a top wall of the container.

As disclosed above, the location of the liquid fuel outlet passageway can be varied for some of the embodiments of the liquid fuel reservoir of the invention without affecting the aims of the invention. FIGs. 36 and 37 illustrate two more examples of varying the location of the liquid fuel outlet passageway for an embodiment of the liquid

fuel reservoir having the external volume of the wicking structure minimized. The
embodiments of FIGs. 36 and 37 are the same as that according to FIG. 18 except for
the location of the liquid fuel outlet passageway. A liquid fuel reservoir **234, 236** is
provided having a container **412, 422** that defines a volume **416, 426** for holding a liquid
fuel mixture (FIGs. 36 and 37). A wicking structure **414, 424** in the shape of two vertical
posts linked to a crossbar at the top is provided along the inside surfaces of the top and
side walls of the container **412, 422**. In the embodiment according to FIG. 36, an outlet
tube **418** and inlet tube **420** extend through a side wall of the container. In contrast, an
outlet tube **428** and inlet tube **430** extend through a bottom wall of the container in the
embodiment of FIG. 37. The outlet tube **418, 428** is in liquid communication with the
wicking structure **414, 424**. The inlet tube **420, 430** has a one-way valve (**421, 431**) that
permits the entry of a gas into the container and prevents the outflow of any liquid. The
wicking structure **414, 424** extends substantially from the front to the back of the volume
416, 426 inside the container **412, 422**, for example, by directly contacting the front and
back walls of the container or by almost contacting the front and back walls. The
present invention includes other embodiments of the liquid fuel reservoir that differ from
the embodiments illustrated in the application in the location of the liquid fuel outlet
passageway and/or the inlet.

FIGs. 33, 34 and 35 show three embodiments of the recyclable liquid fuel
reservoir of the invention having the external volume of the wicking structure minimized.
The liquid fuel reservoir **228, 230, 232** includes a container **382, 392, 402** defining a
volume **286, 296, 406**, a wicking structure **284, 294, 404** in the shape of a rectangular
rim, and an outlet tube **388, 398, 408** and an inlet tube **390, 400, 410** extending through
the top wall of the container. The outlet tube **388, 398, 408** is in liquid communication
with the wicking structure **384, 394, 404**. The inlet tube **390, 400, 410** contains a one-

way valve (391, 401, 411) that permits the inflow of a gas and prevents the outflow of any liquid. The wicking structure 384, 394, 404 is in contact with substantially the entire internal surfaces of the top, side and bottom walls of the container 382, 392, 402.

Although not shown, the wicking structure 384, 394, 404 extends substantially from the front to the back of the volume of the container 382, 392, 402. All the extremities of the volume inside the container are in liquid communication with the wicking structure via at least capillarity. The embodiments of FIGs. 33, 34 and 35 differ only in the means described below that allows the introduction of fresh liquid fuel into the container to replenish any liquid fuel which has been discharged.

In the recyclable liquid fuel reservoir of FIG. 33, a sealable, detachable cap 383 having a membrane 385 is provided at the end of the outlet tube 388. After the liquid fuel inside the container has been partially or completely discharged, the outlet tube can be disconnected from a liquid fuel cell or liquid fuel reformer and capped with the sealable cap 383. To replenish the container with a liquid fuel, fresh liquid fuel in a syringe can be introduced into the container 382 via injection after the membrane 385 is punctured with a syringe needle. When the syringe needle is withdrawn from the membrane 385 after the container is replenished with the liquid fuel, the membrane provides a liquid seal allowing the liquid fuel reservoir 228 to be stored or shipped for the next use. Alternatively, to replenish the container with a liquid fuel, fresh liquid fuel can be introduced into the container through the one-way valve of the inlet tube 390 after the outlet tube 388 has been capped with the sealable cap 383.

In the recyclable liquid fuel reservoir of FIG. 34, a two-way valve 393 is provided in the outlet tube 398. After the liquid fuel inside the container has been partially or completely discharged, the outlet tube can be disconnected from a liquid fuel cell or liquid fuel reformer and closed off with the two-way valve 393. To replenish the

container with a liquid fuel, fresh liquid fuel can be introduced into the container **392** through the outlet tube **398** after the two-way valve **393** is opened, or through the one-way valve of the inlet tube **400** while the two-way valve **393** remained closed. After the container is replenished with the liquid fuel, the liquid fuel reservoir **230** can be stored or shipped for future use (if the two-way valve **393** has been open for liquid fuel replenishment, the valve should be turned off for storage or shipment).

In the recyclable liquid fuel reservoir of FIG. 35, a sealable, detachable cap **403** is provided for the outlet tube **408**. The cap **403** is not attached to the outlet tube when the outlet tube is connected to a liquid fuel cell or liquid fuel reformer. After the liquid fuel inside the container has been partially or completely discharged, the outlet tube **408** can be disconnected from the liquid fuel cell or liquid fuel reformer. To replenish the container with a liquid fuel, fresh liquid fuel can be introduced into the container **402** through the inlet tube **410** via the one-way valve with the cap **403** not attached to the outlet tube **408**, so that the outlet tube can act as a gas vent. After the container is replenished with the liquid fuel, the outlet tube **408** is closed with the cap **403** allowing the liquid fuel reservoir **232** to be stored or shipped for future use.

The recyclable liquid fuel reservoirs of FIGs. 33-35 are related to the liquid fuel reservoirs of FIGs. 20 and 21 in that the wicking structures of these liquid fuel reservoirs all have a configuration of a rectangular rim. The recyclable liquid fuel reservoirs of FIGs. 33-35 result from modifications of a liquid fuel reservoir similar to the embodiments of FIGs. 20 and 21 by adding a sealable, detachable cap with or without a membrane or a two-way valve at the outlet tube. Similar modifications can be made to the liquid fuel outlet tubes of other embodiments, .e.g. the embodiments of FIGs. 18, 19, and 22-32, of the liquid fuel reservoirs to make recyclable versions of the liquid fuel

reservoirs. These recyclable versions of the liquid fuel reservoirs are also within the scope of the invention.

FIGs. 38-40 show three embodiments of the liquid fuel reservoir of the invention in which the external volume of the wicking structure is minimized. The liquid fuel

5 reservoir **237** in FIG. 38 comprises a container **432** having a square or rectangular cross section and six walls (two end walls and four lateral walls) defining a volume **436**

for holding a liquid fuel inside the container. There is a wicking structure **434** having three contiguous sheets of wicking material disposed adjacent to three of the lateral walls of the container. An edge of the sheet of the wicking material is disposed

10 proximate one of the end walls and the opposite edge of the sheet of the wicking material is disposed proximate the remaining end wall. In the embodiment shown in FIG. 38, an outlet passageway **438** and inlet **440** extend through one of the end walls.

The liquid fuel reservoir **238** in FIG. 39 comprises a container **442** having a square or rectangular cross section and six walls (two end walls and four lateral walls) defining a

15 volume **446** for holding a liquid fuel inside the container. There is a wicking structure **444** having four contiguous sheets of wicking material disposed adjacent to the lateral walls of the container. An edge of the sheet of the wicking material is disposed proximate one of the end walls and the opposite edge of the sheet of the wicking

material is disposed proximate the remaining end wall. In the embodiment shown in

20 FIG. 39, an outlet passageway **448** and inlet **450** extend through one of the end walls.

The liquid fuel reservoir **239** in FIG. 40 comprises a cylindrical container **452** having a circular cross section and three walls (two end walls and a curved lateral wall) defining a

volume **456** for holding a liquid fuel inside the container. There is a wicking structure **454** having a sheet of wicking material disposed adjacent to the curved lateral wall of

25 the container. Two opposite edges of the wicking structure are disposed proximate the

two end walls of the container. In the embodiment shown in FIG. 40, an outlet passageway **458** and inlet **460** extend through one of the end walls.

FIGs. 41 and 42 show one of the embodiments of the liquid fuel reservoir **472** of the invention in a cylindrical shape. The reservoir has a wall **462**, which defines a volume **466**, an inlet tube **470** with a one-way valve **471**, and an outlet tube **468**. Inside the reservoir is a wicking structure **464**, which comprises two horizontal circular plates proximate the internal surfaces of the two circular ends of the cylindrical reservoir interconnected with a central stalk extending through the volume **466**.

FIGs. 43-48 show some of the embodiments of the liquid fuel reservoir of FIG. 18 having at least one porous internal compartment **241**, which contains an impurities scavenger (not shown). FIG. 45 shows an embodiment having only one porous internal compartment **241**. FIG. 46 shows another embodiment having two porous internal compartments **241**, **243**. FIGs. 47 and 48 show two alternative embodiments of the liquid fuel reservoir of FIG. 46, wherein the two porous internal compartments are separated (FIG. 47) or joined at one end with a third porous internal compartment **245** (FIG. 48). Optionally, the three porous internal compartments **241**, **243** and **245** can be merged and replaced with one porous internal compartment having a cross section shaped like the alphabet letter, "U."

FIGs. 49-51 show one of the embodiments of the liquid fuel reservoir of FIG. 18, having one porous internal compartment **247** proximate the internal surface of a wall of the container, wherein the internal surface is devoid of the wicking structure **244**.

FIGs. 52-55 show some of the embodiments of the liquid fuel reservoir of FIG. 20 having at least one porous internal compartment **251** (FIGs. 52 and 53) or two porous internal compartments **251**, **253** (FIG. 54). The embodiments have a wicking structure

254 shaped like a rectangular rim that lines the internal surfaces of two side walls and two end walls (FIGs. 52 and 55).

FIG. 56 shows an embodiment of the liquid fuel reservoir of FIG. 24 having two porous internal compartments **292**, **293** containing an impurities scavenger (not shown).

5 FIGs. 57-60 show one of the embodiments of the liquid fuel reservoir of FIG. 40 having two porous internal compartments **451**, **453**, each in the shape of a circular disk containing an impurities scavenger (not shown).

FIGs. 61 and 62 show one of the embodiments of the liquid fuel reservoir of FIG. 41 having a porous internal compartment **461** in the shape of a cylinder disposed proximate a portion of the internal surface of the circular wall of the cylindrical liquid fuel reservoir, wherein the portion is free of the wicking structure **464**.

10 FIG. 63 shows one of the embodiments of the liquid fuel reservoir of FIG. 38 having two porous internal compartments **431**, **433** each in the shape of a square or rectangular flat plate, with the two porous internal compartments disposed proximate a portion of the internal surface of the top and bottom end walls of the container of the reservoir.

15 The liquid fuel reservoirs of the invention can contain an impurities scavenger in the outlet passageway or a filter cartridge connected to the outlet passageway. For instance, FIG. 64 shows an embodiment of the liquid fuel reservoir of FIG. 18 having an impurities scavenger **249** either in an outlet passageway **248** (FIG. 64A) or in a filter cartridge **800** connected to an outlet passageway **258** (FIG. 64B). The outlet port **810** of the filter cartridge **800** can be attached, directly or indirectly via a pump (not shown), to a liquid fuel cell (also not shown).

25 Examples of some of the embodiments of the liquid fuel reservoir of the invention having an impurities scavenger are shown in FIGs. 65-67. FIGs. 65, 66 and 67 show

some of the embodiments of the liquid fuel reservoirs of FIGs. 20, 21 and 41, respectively, wherein the impurities scavenger **259, 269, 469** is located inside an outlet passageway **258, 268, 468**.

The volume inside the containers of liquid fuel reservoirs shown in all the drawings can contain a liquid fuel, which optionally has an ingestion deterrent and/or flame brightener.

It is desired to have a fuel reservoir with a 90% or greater, preferably 95% or greater, efficiency in delivery of fuel to a liquid fuel cell or reformer. In this context, percent efficiency means the maximum amount of the fuel that can be drawn out of the container divided by the amount of fuel that was initially loaded into the fuel-empty container of the fuel reservoir. Depending upon the design parameters and use conditions, greater or lesser efficiencies may be acceptable.

Example 1

An experiment was conducted to determine the removal of non-volatile residues (NVR), as impurities, from methanol by the following impurities scavenging substances: granulated carbon (203-67), granulated carbon (203-75A), Norit Darco G-60 (203-75B) and Calgon carbon (203-75D). NVR had been extracted from a piece of foam into the methanol to form a methanol solution containing NVR to be used in the impurities removal experiment. Separately for each of the above impurities scavenging substances, approximately 150 ml of the methanol solution containing NVR was placed in a beaker with a magnetic stir bar and the impurities scavenging substance was added in the amount shown in the table below, mixed for at least 24 hours, subjected to filtration if necessary to remove the impurities scavenging substance, distilled to

dryness and weighed to determine the amount of NVR remaining. A control run was performed to determine the weight percent of NVR in the methanol not exposed to the impurities scavenging substance and the weight percent determined in the control run was used to calculate the expected amount of NVR in the methanol solution mixed with each of the impurities scavenging substances. The calculated expected amount of NVR was compared to the actual amount of NVR remaining after the removal of the impurities scavenging substance to calculate the percent of NVR removed by the impurities scavenging substance. Typical concentrations were less than 0.5% NVR in the methanol solution. As shown with the data below, the experiment demonstrated that the impurities scavenging substances can be used in powdered, granulated or pelletized form to remove impurities from the liquid fuel.

		203-67		203-75A		203-75B		203-75D
		Granulated C		Granulated C		Norit Darco G-60		Calgon C
		<i>Packet Treat</i>				<i>Carbon</i>		<i>Pulverized Powder</i>
D50% Particle Size		<5 mm		<5 mm		<45 microns		<1mm
Gross		40.8502		40.3634		40.3449		41.1427
Tare		40.8419		40.3554		40.3391		41.1381
g NVR		0.0083		0.0080		0.0058		0.0046
Expected g NVR		0.0597		0.1074		0.1046		0.1061
g NVR scavenged		0.0514		0.0994		0.0988		0.1015
% NVR scavenged		86.1%		92.6%		94.5%		95.7%
g Carbon		2.1		4.1		4.1		4.1
Contact Time w/Solution		40 hrs		40 hrs		42 hrs		184 hrs
g NVR scavenged per g C		0.0245		0.0242		0.0241		0.0248

The invention has been illustrated by detailed description and examples of the preferred embodiments. Various changes in form and detail will be within the skill of persons skilled in the art. Therefore, the invention must be measured by the claims and not by the description of the examples or the preferred embodiments.